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GEOLOGY AND WATER RESOURCES OF NEZ PERCE
COUNTY, IDAHO, PART II.—RUSSELL

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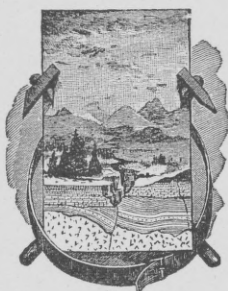
UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES OF
NEZ PERCE COUNTY, IDAHO

PART II

By ISRAEL COOK RUSSELL



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GEOLOGY AND WATER RESOURCES OF NEZ PERCE COUNTY, IDAHO.

PART II.

By ISRAEL C. RUSSELL.

WATER SUPPLY.

The sources of water supply in the Nez Perce region are streams, springs, wells, and cisterns. Of these special attention can be given here to only the springs and the drilled wells, for it is from these that the water supply must be supplemented. There are splendid rivers of clear, wholesome water flowing through this country, but they are in deep valleys and in canyons with steep, rugged walls, and for the most part are practically unavailable for economic purposes, on account of the expense of pumping or of constructing aqueducts which will conduct the water to where it can be used. Although the utilization of the surface waters can not be considered in detail in this report, a brief account of what has been accomplished in that direction will be serviceable as indicating the needs of an increased water supply. In this region water is used for navigation, irrigation, town supply, power purposes, household use, and the watering of stock.

The first of these, navigation, may be dismissed for the present with the statement that Snake River is the only stream that is navigable or that it is practicable to render navigable, on a commercial scale, for steamboats.

Fortunately, the rainfall, on account of the retentive character of the soil, is sufficient to insure good crops on all but the lowest plateaus and on the canyon walls; but in most places the results could be made still more satisfactory if recourse could be had to irrigation, especially during the height of the dry season. The areas where irrigation is now practiced are small, and most of them are along the borders of Snake and Clearwater rivers. By far the most important and successful attempt that has been made to utilize the streams is the ditch constructed by the Lewiston Water and Power Company, which diverts water from Asotin Creek about 6 miles above its mouth and at an approximate elevation of 665 feet above Snake River at Asotin, and conducts it $14\frac{1}{2}$ miles to Clarkston, where part of it is

distributed, through underground mains and laterals, for town purposes and irrigation. The upper $6\frac{1}{2}$ miles of the system is a flume 6 feet wide and $3\frac{1}{2}$ feet deep, with a grade of 10.56 feet to the mile. This flume is on the steep northern wall of Asotin Canyon, and is carried across the numerous lateral gulches on trestles. The lower 8 miles of the system is a canal 6 feet wide at the bottom and 16 feet wide at the top, with a depth of 5 feet and a grade of 2.12 feet to the mile. The estimated capacity is 127 cubic feet per second.

Lewiston is supplied with water by a pumping station in the eastern portion of the city, which takes water from Clearwater River. Asotin derives its water supply principally from a gravity system supplied by ditches which divert water from Asotin Creek, but surface wells are also in use there. Asotin Creek also supplies power for an electric-light plant, from which electricity for illumination is distributed to Asotin, Clarkston, and Lewiston. Flouring mills in Asotin and Lewiston are run by water power. Additional sources of water power which are not yet utilized but which demand careful investigation, are to be found on Grande Ronde River, at Waha, and along Salmon River and Orofino Creek. For household purposes in villages and on farms recourse is had in most instances to ordinary surface wells, and in favored localities to springs and streams. The surface wells on the lava plateaus derive their water from the residual soil and subsoil, as a rule at a depth of from 30 to 50 feet, but the supply is frequently small and not of good quality, on account of mineral matter in solution. Drilled wells have been put down in a few cases, and some of them, as will be noted later, are very successful.

On the whole, despite the large volumes of the streams, which, as already stated, it is impracticable to utilize except in a few instances, there is a dearth of water in this region, and there is urgent need, particularly on the plateaus where grain is so largely grown, of water for household use, for the irrigation of gardens and orchards, and for watering stock; also to supply villages, in order that the surface wells may be abandoned and sanitary drainage established. And it is hoped that the improvement of springs and the sinking of artesian wells will furnish relief in many instances.

SPRINGS.

At the bottom and on the sides of the canyons and gulches excavated in the Columbia River lava, water issues as springs at many localities, but as a rule soon disappears, owing to the quantities of loose material mantling the surface. These springs are supplied by water percolating through porous beds composed, in most instances, of gravel, sand, or volcanic dust, and, less commonly, of the scoriaceous portions of the lava sheets themselves. The source of the water where the porous beds are in the upper portion of the Columbia River lava and where it has been dissected by streams to the depth

of the porous beds or lower, as in the case of the Clarkston, Lewiston, Camas, and Kamiah plateaus, is the rain falling on the broad inter-stream areas. The rain water is absorbed by the deep porous soil and subsoil, which usually is traversed by vertical tubes, as explained in Part I, and finds its way through the surface sheets of lava, for they usually are more or less decayed and broken by joints, and thus readily reaches any porous beds which may be present in the upper portion of the lava formation.

In some cases, however, e. g., where the strata dip away from a canyon wall, as along the south side of Clearwater River throughout the lower 20 miles of its course and on the south side of Snake River between Clarkston and Alpowa, the rain water falling on the exposed edges of the porous layers in the canyon walls, or reaching them by flowing down the slopes above, follows the inclined beds and comes to the surface in the next canyon, in the direction of the slope, which is sufficiently deep. In the neighborhood of the mountains bordering the region occupied by the lava, the gravel beds between the layers extend up the valleys to the uplands, and there are abundantly water charged. Wherever such beds have been cut by erosion, springs appear. The conditions favoring the origin of springs are increased in a most important manner by the fact that at least one widely spread bed of sand and gravel in the upper portion of the lava formation is underlain by a thick, impervious layer of clay. This double layer, consisting of sand and gravel above and clay below, as already described, underlies the Uniontown and the Lewiston-Clarkston plateaus, and probably extends eastward to the border of the Columbia River lava. The depth of the surface of the sand and gravel varies from 150 to 350 feet. The most definite sections showing its position and character are furnished by the well on Ira Small's ranch and by the exposure in a neighboring gulch.

As already explained, this soft layer has influenced the topography of the canyon walls over a wide extent of country, and its position in many localities is indicated approximately by the presence of a terrace on otherwise precipitous slopes. Near the heads of small canyons, where they first reach the horizon of the surface of the clay beneath the sand and gravel member of the sedimentary deposit, springs frequently are present. Their occurrence at these localities is due to the fact that the edge of the porous bed is there most often exposed. Owing to the quantities of more or less disintegrated rock encumbering the terrace, and especially the thick talus piles and landslides on its border adjacent to the cliffs rising above it, the water which flows out is lost to view. There is no doubt that if this surface débris could be removed an abundant outflow of water would be obtained in many places where now there is no sign of its presence. This perhaps seemingly bold statement is sustained by the fact that in prospecting for lignite on S. C. McNeil's ranch, in Grande Ronde Canyon,

a tunnel was driven in a most unpromising locality so far as water was concerned—in a landslide—and encountered such a volume of water as seriously to impede mining operations.

A typical illustration of the class of springs referred to is furnished at the head of a small gulch opening into the valley of Clearwater River near the Small ranch. Here, as already explained, erosion has cut through a layer of sand, about 60 feet thick, resting on clay. Springs appear at the surface of the clay, and the natural conditions have been improved by the removal of the loose rocks which had fallen in from above, and the placing of a pipe for conducting the water away. The strata dip southward, or away from the escarpment overlooking Clearwater River. The intake of the layer of sand is principally on the north face of the escarpment, and its flow through the bed is southward, down the slope. As will be more fully described further on, the water supply in this instance could be still further increased by excavating a tunnel, or "horizontal well," in the base of the sand layer, in a direction (eastward) at right angles to its dip.

Other examples of springs similar to the one just described are to be seen near the heads of several of the gulches which open into Asotin Creek within a radius of 10 miles of the town of Asotin. In the region referred to there are well-defined terraces about 120 and 260 feet below the general level of the adjacent plateaus, each of which is due to a sedimentary bed interstratified with the basalt. In descending the side gulches leading to the main creek, springs are found when these terraces are reached, their presence usually being indicated by a house, for in nearly every instance they have led to the location of a homestead.

The conditions on Asotin Creek are repeated along the "break" of Snake River Canyon, more particularly on its west side between Asotin and the mouth of Grande Ronde River, where a terrace is present. Below the first rim rock, and apparently dangerously near the brink of the great precipices below them, several houses are to be seen from the hills near Waha; and each house marks the location of a spring.

Other illustrations of these conditions might be offered, and many will doubtless suggest themselves to persons who are familiar with the marvelous advances that have been made in the development of the agricultural resources of the Nez Perce region. But facts enough have probably been offered to sustain the recommendation which follows, in reference to the practicability of greatly increasing the water supply derived from the pervious beds cut through by the larger canyons and many of their tributary gulches.

HORIZONTAL WELLS.

The pioneer experiment in this connection should be in the direction of enlarging an existing spring, as, for example, the one at the

head of a small gulch near Ira Small's ranch. At that locality a tunnel should be excavated at the base of the sand, its bottom being at the start perhaps 2 feet below the surface of the underlying clay, and carried eastward at least 200 or 300 feet. The longer the tunnel the greater will be the quantity of water obtained. In this and all similar instances the proposed tunnel should run at right angles to the dip of the beds, or as nearly in that direction as is practicable and still obtain the necessary slope. There are many localities nearly or quite as favorable as the one cited, for example, along the upper portion of the great escarpment bordering the Uniontown Plateau on the south, and particularly near the heads of the notches cut in its rim, and again near the head of the gulches tributary to Asotin Creek. In Tammany Hollow the same porous layer which underlies the Uniontown and Clarkston plateaus is cut through, and springs appear at its base. It is the presence of these soft beds which has given the hollow its exceptional width upstream from the place where the underlying sheet of basalt is exposed. The beds there dip gently northward, and tunnels made for the purpose of obtaining water should be located on the south side of the valley. As will be explained more fully further on, it is desirable either that two tunnels be constructed, diverging from each other at a high angle, or that a main tunnel be run directly into the bluff at the base of the porous layer, and then branched like the letter Y, but at a wide angle.

The principal conditions governing the selection of a locality for excavating a tunnel or horizontal well, in case the strata are essentially horizontal, should be the presence of a broad plateau surface, which will serve as a catchment area for rain, and a break on the border of such an area where the underlying porous beds are cut through. The most favorable localities, as suggested by existing springs, are near the heads of small gulches excavated in the borders of broad plateaus. The presence of a soft bed, as already explained, is usually indicated by a terrace in the canyon walls, but may also be discovered by observing the nature of the surface *débris*. The coarser sedimentary beds usually contain well-worn pebbles of various kinds of rock, among which white quartz is frequently conspicuous. Such pebbles mingled with the surface *débris* furnish evidence regarding the position of the layer from which they came, similar in all respects to that supplied by "float" in ordinary prospecting. When the actual presence of a porous bed has been determined, its base must be reached; and for this purpose a cut will usually have to be made in the nearly universal sheet of *débris* which mantles the surface. On a slope where the presence of a layer of gravel is revealed in the surface material, but where no actual exposures are in sight, as is the nearly universal rule, the most practical method will be to sink prospecting pits at various horizons below the highest level at which the gravel or sand "float" appears, until the base of the layer is dis-

covered. The direction and character of the proposed tunnel will depend on the local conditions.

In order to make the suggestions just offered more tangible, fig. 5 has been prepared. This figure illustrates most of the conditions that will be met with in the Nez Perce region. It represents a plateau composed of horizontal lava sheets and containing one sedimentary bed near the surface, which has been deeply trenched by erosion. The view is supposed to be from one side of a deep canyon, and shows the strata exposed in the opposite wall and in the connecting side canyon and gulches. The most favorable localities for horizontal wells would be at *a*, *b*, and *c*, and the general direction they should take is indicated by dotted lines. In each case two tunnels are suggested, the object being to intercept as much of the percolating water as practicable. The length of the tunnels will be controlled by local

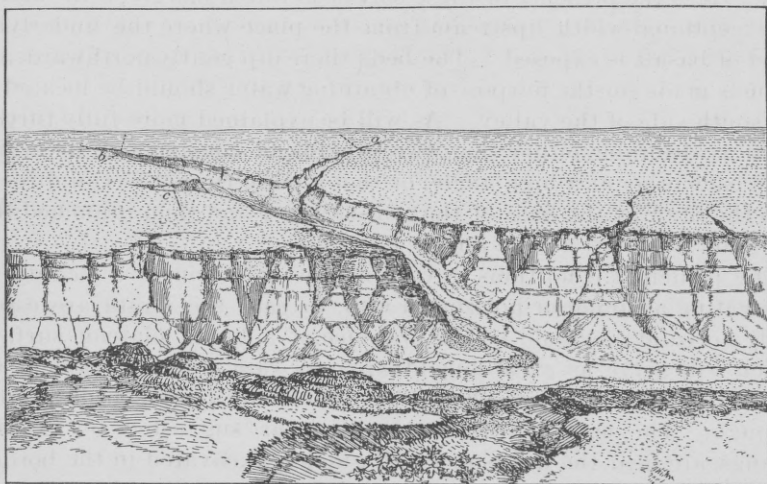


FIG. 5.—Dissected lava plateau, showing best locations for horizontal wells.

conditions, but in general, in the region about Lewiston they can be extended almost indefinitely, the ratio between expense and water supply being the governing factor.

In the illustration horizontal strata are indicated. The most favorable conditions would be furnished, however, where the strata beneath a broad plateau dip toward a canyon wall in which the cut edge of a porous layer is exposed. For example, if the strata shown in fig. 5 dipped toward the point of view, one tunnel only would need to be run at *a*, while at *c* the chances of obtaining water would not be worth considering. If the strata should be inclined downward from right to left, two tunnels at *a* would be advisable, as indicated, but only one running in the direction of the line of the gulch would be required at *b*, while at *c* no water could be obtained. The sketch may perhaps be considered as indicating that springs would occur all

along the canyon walls, and such, to some extent, would no doubt be the case under similar conditions; but the canyon walls, at least in the Nez Perce region, are so heavily sheathed with *débris* that only an unusually strong spring can give surface indications of its presence, except near the head of a small gulch. More than this, when a pervious bed is exposed for miles in the wall of a canyon there is such freedom for the water it contains to escape by seepage that definite springs are not likely to occur. Near the heads of lateral canyons and gulches, however, the conditions are different, and a concentration of the percolating waters is favored. The writer repeats the suggestion that the most favorable localities for excavating horizontal wells are near the heads of small gulches where pervious beds are first cut through.

Considerable space has been given to the consideration of the conditions which favor success in searching for water by means of horizontal wells, for the reason that through the lava-covered portion of the Nez Perce region and a still greater area of similar character in the neighboring portions of Washington and Oregon, there is a combination of circumstances—such, for example, as deep porous soils and subsoils which absorb rain water, the presence of sedimentary beds between the lava sheets, the manner in which the surface layers of lava are weathered, the deep canyons with small lateral branches that abound, etc.—which justifies the making of trials in this connection at numerous localities.

In the last few pages attention has been directed mainly to the sheet or sheets of porous beds near the surface of the Columbia River lava, because these are favorably situated to be supplied by local precipitation. There are other similar beds, however, at varying depths, down to more than 3,000 feet, as has previously been explained, and where any one of these appears in a canyon wall and is underlain by an impervious bed horizontal wells may be expected to yield a water supply. The most favorable of these localities are where the pervious beds first appear as one descends a canyon which has been cut sufficiently deep to reach them.

ARTESIAN WELLS.

GENERAL PRINCIPLES.

An artesian well is understood to be an excavation in the rocks, usually a hole a few inches in diameter made by drilling, through which water rises to the surface and overflows. No definite line can be drawn between wells that are truly artesian and many others in which water rises by hydraulic pressure, except in reference to a surface flow.

The primary condition necessary to the obtaining of flowing water by drilling is that water exists under sufficient pressure to force it to

the surface when an opening is made for its escape. The force which sends the water to the surface is, in most instances, the pressure of water at higher levels; that is, hydraulic pressure.¹ This is illustrated by the manner in which many towns are supplied with water from storage reservoirs. There is no difference in principle between an artesian well and the flow of water from a faucet in one's kitchen, and a continuous and nonperforated tube through which water can rise is as essential in the case of an artesian well as it is in the water mains and laterals of a city.

Experience has shown that the most usual conditions which permit the accumulation of water in rocks so as to be under pressure are the presence of a porous bed, such as gravel, sand, and even quite compact sandstone, or beds of much more impervious rock traversed by fissures inclosed between two water-tight or impervious beds or strata, such as clay, shale, etc., and the series thus arranged having a basin shape or rising in all directions from a central area. An additional condition requisite to maintaining a continuous flow is that the upraised edge of the porous water-charged layer should be exposed at the surface so that it may receive additional water. These condi-



FIG. 6.—Section illustrating the chief requisite conditions for artesian wells. *A*, a porous stratum; *B* and *C*, impervious beds below and above *A* acting as confining strata; *F*, height of water level in the porous bed *A*, or, in other words, height of the reservoir or fountain head; *D* and *E*, flowing wells springing from the porous water-filled bed *A*. (After Chamberlin.)

tions are illustrated in fig. 6, an ideal section indicating the arrangement of rocks to a depth of a thousand feet beneath a valley 20 miles wide. Other sections across the valley in any direction would show essentially the same conditions.

Rain falling on the exposed edge of the porous bed *A* percolates through it until it becomes thoroughly water charged. The water at any point in the bed is then under the pressure of the waters at higher levels, and if a hole be drilled, as at *D* or *E*, it will rise and overflow at the surface. If a tube be connected with one of these openings and carried up above it, the water would rise in the tube until it stands on a level with the lowest notch in the rim of the water-charged layer. This would determine the *artesian head* for the basin. At all points within the basin where the surface is below the level of the artesian head, a surface flow could be obtained by drilling a well down to the porous layer.

While fig. 6 will, the writer thinks, make clear the primary condi-

¹ Among the agencies which might cause a pressure on water confined in porous beds or in fissures are gas, steam, and the compression of the rocks themselves, owing to the weight of the material resting on them, but examples of flowing wells in which the rise of the water is due to other agencies than hydraulic pressure are, the writer believes, unknown.

tions governing the flow of artesian wells, there are certain important secondary conditions which need to be considered in individual cases. One of these, of special importance to well drillers in the Nez Perce region, is that the rocks above a porous stratum may not be impervious all the way to the surface, or the upper impervious bed may be overlain by porous material, so that water would not rise to the surface where an opening is made, although the pressure be sufficient, unless the well is properly cased so as to prevent lateral flow. Another consideration to be borne in mind is that the rainfall on the exposed margin of the porous layer should be sufficient to maintain the flow of the wells opening into it.

A true basin shape in a porous layer inclosed between impervious beds is not essential to an artesian flow, however, for any porous bed in which water is confined which is so situated that it can be recharged from the surface and an opening be made where the surface is below the intake will permit of a surface flow. For example, in the filling of a valley there may be an alternation of clay and sand, such as is indicated in fig. 7, which would permit the obtaining of a surface flow at the locality marked W.

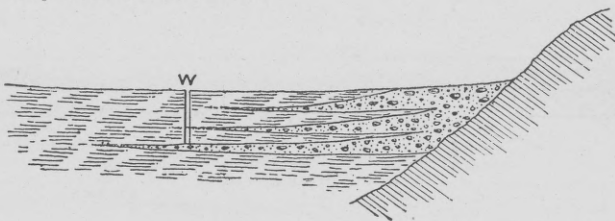


FIG. 7.—Ideal section of the border of a basin deposit, illustrating possible artesian conditions.

In the Nez Perce region the conditions illustrated by both figs. 6 and 7 have to be considered. As has already been described, the Columbia River lava was poured out in successive sheets, and in several instances between adjacent sheets there are beds of clay, sand, gravel, volcanic dust, and lapilli. The layers of clay are impervious, as is also the solid basalt, unless fractured or jointed, while the other beds mentioned are pervious and in a condition to become water charged. If the series of strata referred to should become bent into a basin shape, and the edges of the porous beds be exposed so as to receive water, it is evident that the conditions illustrated in fig. 6 would be produced and artesian wells be possible. Again, from the manner in which the layers of sand, gravel, volcanic dust, and lapilli interbedded with the Columbia River lava were formed, it follows that conditions similar to those illustrated in fig. 7 may be present, even where the rocks have not been deformed so as to produce basins. For example, taking the beds of sand and gravel, which are the most promising, we know that the material forming them was carried by streams and spread over the Columbia River lava at various times

during the periods intervening between the lava floods. In many instances these beds are of the nature of alluvial fans, and are thickest adjacent to the mountains from which the material composing them was derived, and thin out and become finer at a distance from their source. On the lava plains which were overspread in this manner there were at times lakes in which clay was deposited, so that an alternation of pervious and impervious beds may be expected. In this connection it is important to remember that the alluvial deposits spread out between the lava sheets were laid down mainly at the mouths of valleys in the adjacent mountains, and that their summit portions extended far up the valleys. As sheet after sheet of lava was poured out, each successive layer extended farther up the valleys than its predecessor, but probably never covered the higher portions of the alluvial deposits previously formed. Thus the layers of sand and gravel between the sheets of lava are favorably situated for becoming water charged.

The conditions just described may perhaps be made clearer by an

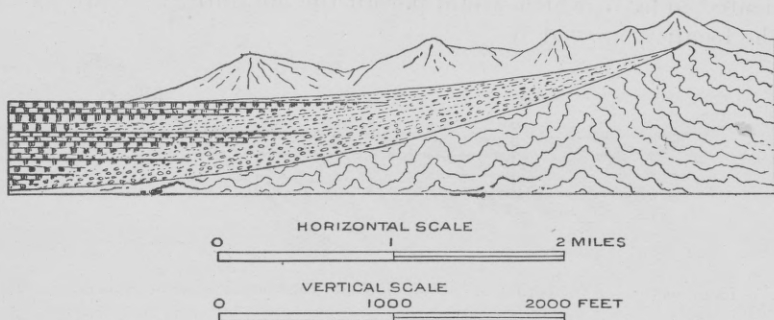


FIG. 8.—Ideal section of the border of the Columbia River lava adjacent to mountains.

examination of fig. 8, an ideal section at the border of the lava formation and extending up a valley in the preexisting mountains. The mountains in the background are intended to represent the far side of the lava-floored valley. It will be noted that this section, which represents the general conditions that obtain about the border of the Columbia River lava, is much like the one forming fig. 7, except that lava flows are added. Under the conditions illustrated it is evident that a well drilled through the lava sheets until a porous water-charged bed is reached should yield a surface flow, provided the mouth of the well is below the exposed portion of the pervious layer, and also provided that there is an unbroken impervious bed both above and below it. What has just been stated in general terms illustrates in a qualitative way the actual conditions in the Nez Perce region.

LEWISTON-CLARKSTON BASIN.

In the region about Lewiston-Clarkston, as already explained, the rocks have been depressed so as to form the Lewiston and Clarkston

plateaus. The northern border of this depressed area is defined by the Clearwater escarpment. The downward inclination of the surface of the plateaus and of the lava sheets, etc., composing them, is northward at a low angle, probably not exceeding 2 degrees. These relations are indicated in fig. 1. The Lewiston and Clarkston plateaus have also been deformed in their relations to each other, the former having been upraised along its eastern and southeastern margins, where it joins Craig Mountain, and the latter upraised along its southwestern margin, where it passes into the Blue Hills uplift. An east-west section across the two plateaus, passing through any point between Clarkston and Asotin, would exhibit the essential features shown in fig. 2.

The resultant of the three main movements which have affected the Lewiston and Clarkston plateaus is such as to give the lava sheets and their contained sedimentary beds an inclination toward the sites of the towns for which they are named. An irregular basin has thus been formed, the deepest part of which is near the center of its northern and sharply upturned border; that is, at Lewiston-Clarkston.

So far as the geologic structure, or the positions which the strata occupy, is concerned, it is evident that the Lewiston-Clarkston Basin has the features requisite for furnishing artesian water. Regarding the necessary succession of pervious and impervious beds, however, our present information is both limited and indefinite. Although the strata are well exposed in canyon walls, no porous layers within an artesian basin cut by canyons, except under certain special conditions, can be expected to retain water under pressure. To learn what strata are present below the bottoms of the canyons one is constrained to study the geology of the surrounding region over a wide area; but such examinations as it has been practicable to make in this connection have not furnished the detailed information desired.

As already stated, porous sedimentary beds highly favorable for the passage of water through them are interstratified with the Columbia River lava in Little Canyon, in the canyon of Orofino Creek, and along the South Fork of Clearwater River at from 750 to 800 feet, and in Salmon River Canyon at 3,500 feet, below the surfaces of the adjacent plateaus. It is possible that one or more of these beds occur in the Lewiston-Clarkston Basin, but positive evidence that such is the case is lacking. There is a probability also that other sedimentary beds not yet recognized may be present.

In addition to the evidence derived from natural exposures, we have, in one successful well, what may be claimed to be a crucial test of the artesian conditions.

Wells in Tammany Hollow.—In Tammany Hollow, about 8 miles southeast of Lewiston and, according to aneroid measurements made by Mr. John Adams, 500 feet higher than Main street in that city, or

about 1,200 feet above the sea,¹ six drilled wells have been put down, four of which furnish flowing water and are true artesian wells. The records of these wells are somewhat indefinite, but the following data concerning them seem to be authentic.

On the farm belonging to Charles Dowd four drill holes have been made. The first of these was begun in 1896, and the others between that year and the summer of 1900. Well No. 1, at Mr. Dowd's house, has a diameter of 8 inches, and, as reported by Mr. Dowd, passes through the following material:

<i>Section at well No. 1, on farm of Charles Dowd.</i>	
	Feet.
Yellowish soil, clay-like in consistency	40
Basalt, hard, mostly black, but with scoriaceous portions	170
Total depth	210

Since this record was obtained, the writer has been informed by Mr. E. H. Libby that this well has been deepened 40 feet and now has a total depth of 220 feet. There is, then, a discrepancy of 30 feet in the records obtained. At the time of the writer's visit (June 28, 1900) this well was cased, but some water rose outside the casing; within the casing water rose to a height of about 20 feet above the ground, but the full height to which it would rise in an open tube was not measured. At an elevation of about 4 feet above the ground the discharge was from 15 to 20 gallons a minute. The deepening and recasing or readjustment of the old casing since the date mentioned, as the writer has been informed by Mr. Libby, resulted in increasing the flow to 105 gallons a minute. The water is clear, tasteless, without appreciable quantities of gas, and evidently of good quality. The temperature, as measured by Mr. John Adams on December 8, 1900, was $58\frac{3}{4}^{\circ}$ F. A copious spring a few rods distant had a temperature of 54° , and the air a temperature of 48° .

Wells Nos. 2, 3, and 4 are in a group within a radius of about 150 feet, about 1,000 feet west of Mr. Dowd's house, and approximately 30 feet higher than the surface at well No. 1. The temperature of these wells, as determined by Mr. John Adams, is from 66° to 68° F.

Well No. 2 has a diameter of 5 inches, and is reported by Mr. Dowd to pass through the following strata:

<i>Section at well No. 2, on farm of Charles Dowd.</i>	
	Feet.
Yellowish clay, with quartz pebbles	30
Soft yellowish clay	70
Basalt	1.5
Sand, soft, "clay sand"	(a few inches)
Total depth about	100

This well is poorly cased, and water rises to the surface and over-

¹ See table of elevations forming Appendix A.

flows both within and outside of the pipe. The flow is estimated to be from 4 to 5 gallons a minute.

Well No. 3 has a diameter of 5 inches, narrowing to 4 inches near the bottom, and passes through essentially the same materials as did well No. 2. Water overflows both within and outside of the casing, and is about the same in volume as in well No. 2.

Well No. 4 has a diameter of 5 inches, and passes through the following strata:

Section at well No. 4, on farm of Charles Dowd.

	Feet.
Clay	75 to 80
Basalt	200
Greenish clay	30
"Slate," soft	3 to 4
Total depth about	314

There is a small surface flow, and the casing is defective.

In reference to wells Nos. 2, 3, and 4 there seems no reason to doubt that if they were cleared out and properly cased a good surface flow of water would be obtained.

About 1 mile north of the wells just described, on the farm of J. A. Nelson, in Tammany Hollow, near its northern border, a well was put down in 1898-99 in which the following layers were passed through, according to the recollection of Mr. Charles Dowd:

Section at well on farm of J. A. Nelson.

	Feet.
Clay	100
Basalt	20
Coarse, sharp sand	3
Basalt	80
Total depth about	200

When the 3-foot layer of sand was penetrated water rose to within 35 feet of the surface, and has since remained at that level. The well is not cased. The water in the porous layer is under pressure, and if the well were properly cased it might be expected to rise to the surface and overflow.

About 2 miles east of the Dowd wells, and in the same valley or hollow, on the farm of A. S. Wisner, where the surface is about 100 feet, by aneroid measurement, above Dowd's well No. 1, a drill hole was put down a few years ago which is reported to have passed through the following strata:

Section on farm of A. S. Wisner.

	Feet.
Gravel	25
Clay, compact	105
Basalt	86
Total depth	216

No water was obtained.

A surface well a few rods distant penetrated the following strata:

Section at well on farm of A. S. Wisner.

	Feet.
Sand and gravel	25
Yellow clay, changing to bluish below	25
Total depth	50

The clay in this well is highly charged with volcanic dust and contains leaf impressions. Water was obtained, by percolation, at the base of the layer of sand and gravel, and the excavation below that level furnishes a reservoir for storing the water which comes in from above.

In addition to the drilled wells noted, there are reports, without details, of a dug well 40 feet deep about 1 mile north of Wisner's well, at a surface elevation 50 feet higher, which is all in basalt and failed to reach water. Also about 1 mile south, on the farm of F. Crutinger, where the surface is about 125 feet higher than at Wisner's well, a well 200 feet, all in basalt, failed to reach water.

At many localities in Tammany Hollow water is obtained in surface wells at depths of from 30 to 40 feet, and along the sides of the valley there are several springs.

The bearing of the evidence obtained in Tammany Hollow, with reference to the artesian conditions in the Lewiston-Clarkston Basin generally, may be summarized as follows:

Tammany Hollow is a basin due to erosion which has cut through the surface sheet or sheets of basalt and exposed a layer of sand and gravel resting on clay. These sedimentary beds are the same as those penetrated by the drill hole on Ira Small's farm, and outcrop on the south side of Clearwater River, as already explained. Tammany Hollow owes its exceptional width (about 1 mile at the bottom) to the widening of the excavation made by the creek which flows down it, in the soft sedimentary beds lying above the sheet of basalt through which the creek has cut. Downstream the valley becomes narrow and the stream flows over basalt. Most of the springs along the side of the valley are fed by water percolating through the upper member of the sedimentary beds, and offer favorable opportunities for increasing their flow by means of horizontal wells, as already explained.

The drilled wells, the records of which, so far as available, have been presented, all start in the sedimentary beds referred to, but, with the possible exception of the Nelson well, evidently do not derive an appreciable portion of their water supply directly from that source. This is evidenced by the fact that the porous upper member of the sedimentary beds has been cut through by erosion, and although furnishing springs it can not be expected to retain water under sufficient pressure to cause a surface flow in a well begun at an elevation of a hundred feet or more above the bottom of the hollow. More than this, the same sheets of sedimentary material have been cut by Snake

River, Sweetwater Creek, and other streams, and can not be expected to convey water from a distance. Additional evidence is furnished by the temperatures of the Dowd wells, which, as already recorded, are $58\frac{3}{4}^{\circ}$ and 66° to 68° . The mean annual temperature in Tammany Hollow, as near as can be judged from the climatic records of the region in which it is situated, is from 48° to 49° F. As is well known, seasonal changes in temperature in localities of similar geographic position to the one under consideration disappear at a depth of about 50 feet below the surface. At that horizon there is a uniform temperature which corresponds with the mean annual temperature at the surface. Below that horizon there is an increase in temperature of about 1° F. for approximately each 60 feet in depth. The well at Mr. Dowd's house has a temperature of $58\frac{3}{4}^{\circ}$, which indicates that its water comes from a depth of at least 540 feet, while the three wells about 1,000 feet to the westward have temperatures ranging from 66° to 68° and must be supplied from a depth of at least 1,140 feet.

Here we are met with the apparently anomalous fact that well No. 1, with a strong flow, is 10° lower in temperature than the neighboring well, with a weak flow; but as wells Nos. 2, 3, and 4 are practically uncased, the actual amount of water rising from a depth is perhaps even greater than is discharged by well No. 1, which has a fairly good casing. Well No. 4, however, is about 100 feet deeper than well No. 1 and should have a somewhat higher temperature, and under the conditions present it may be expected to influence the temperature of the wells drilled near it.

The only conclusion which seems justifiable in reference to the source of the water at the Dowd wells is that it comes from a depth of more than 1,000 feet below the surface, through fissures in the Columbia River lava, and in part spreads out in the interstratified porous sedimentary beds. The spring near Mr. Dowd's house has also a deep source, as is shown by its temperature, but, the water rising less freely than in the neighboring wells, in its passage upward it is cooled to 54° . The recent deepening of well No. 1, which increased its flow, is also in harmony with the conclusion that its water is received from fissures.¹

Recommendations.—The success of the Dowd wells must be considered highly favorable to obtaining artesian water throughout a large area within the Lewiston-Clarkston Basin, but it is not as reassuring as might be wished, for the depth below the surface from which the water comes is not definitely shown. It is very encouraging to know, however, that at a depth of about 1,000 feet a porous stratum probably exists which contains water under sufficient pressure to cause a surface flow at an elevation of more than 500 feet above Lewiston. A word of caution is perhaps necessary here, inasmuch as the

¹ It may be suggested that if a charge of dynamite were exploded at the bottom of this well its flow would be still further increased.

facts in hand do not prove the presence of a water-charged stratum. There is a possibility that the water referred to finds its way from distant uplands through fissures, but what is known concerning the presence of sedimentary beds at various horizons in the Columbia River lava does not favor this view.

Having before us all of the facts which it is practicable to obtain at the present time concerning the general question of procuring artesian water in the Lewiston-Clarkston Basin, the conclusions must be largely controlled by considerations of expense. No one can say positively that success would follow the putting down of a drill hole at a certain locality, but from a geologic point of view the experiment is well worth trying. The most favorable location for the pioneer well is in the lowest part of the basin, and, fortunately, that is where the demand for water is greatest. The lowest level of the basin is at Lewiston-Clarkston, but the test should be made at as great a distance as practicable from the Clearwater escarpment. The writer recommends that a boring be made in Lewiston, preferably on the upper terrace on which the newer portion of the city is built, as, for example, in proximity to the public-school building. The chances, however, are equally good, and possibly better, in Clarkston. If the latter locality is chosen, the boring should be made in the western portion of the city, near the base of the "first bench." If a trial is made at either of these localities, the boring should be carried down to a depth of at least 3,000 or 4,000 feet, unless a sufficient water supply is obtained at a less depth, or the formations which underlie the Columbia River lava are reached. There would be no excuse for continuing to drill after granite, diorite, mica-schist, limestone, shale, etc., are entered; but soft beds containing the débris of such rocks must not be mistaken for the rocks themselves in place. A successful boring at either of the localities recommended would establish the artesian head of the basin and indicate the horizon below which other wells might be expected to yield a surface flow. Owing, however, to the lack of knowledge concerning the topography of the old land surface over which the Columbia River lava was outpoured, all portions of the basin below the artesian head determined from a pioneer well might not yield equally favorable results. The presence of diorite ("granite") blocks on the hillside a mile or two southeast of Lewiston and the reported discovery of similar rock in place near the same locality seem to indicate that the older formations there rise through the lava. If this be true, the region immediately about Lewiston-Clarkston would probably be cut off from the source of water which supplies the wells in Tammany Hollow.

CAMAS-KAMIAH BASIN.

To the east of Craig Mountain, and intervening between that uplift and the foothills of the Bitterroot Mountains, is a broad, shallow, structural basin, the nearly flat central part of which is occupied by

the Camas and Kamiah prairies. The rim of the basin is well defined on all sides, except perhaps to the north, where the Craig Mountain monoclinical fold flattens out. The dip of the sheets of lava away from the uplands of older rocks to the eastward is slight, but judging from the inclination of the plateau remnant between the streams, it is definite and continuous for a distance of several miles toward the center of the depressed area. Within the basin, as already described, there are thick beds of sandstone, shale, etc., interstratified with the lava sheets. Thus the conditions in reference to both geologic structure and succession of beds in general favor the existence of water under pressure in the porous beds. Information concerning the composition and order of succession of the strata below the depths to which canyons have been cut is wanting. The canyons in the central portion of the basin, as Lawyers Canyon and Little Canyon, have a depth of about 1,000 feet, and the South Fork of Clearwater River flows through a canyon fully 1,800 feet deep. No water under sufficient pressure to cause a surface flow could therefore be expected at a less depth than the canyons have been cut, except, as will be explained further on, where broad plateau remnants adjacent to the mountains exist between the streams.

The success of deep wells in this basin, or in the Lewiston-Clarkston Basin, hinges on the presence or absence of the requisite succession of pervious and impervious beds and the topography of the old land surface beneath the lava. Neither of these uncertain factors can be determined from natural exposures, although some light respecting the succession of beds beneath the Camas Prairie may perhaps be obtained in Salmon River Canyon, and must be discovered, if learned at all, by means of the drill. The basin is, however, situated so near the mountains bordering the Columbia River lava that it is more than likely several sedimentary beds exist and that the requisite arrangement of one or more pervious beds between impervious ones is present. In the writer's opinion, the conditions in this basin are such as to warrant the drilling of a test well, provided the demand for water is sufficient to justify the expense. The pioneer well should be located in the lowest portion of the basin, as, for example, in the vicinity of a line joining Cottonwood, Howard, and Steele, or midway between Kippen and Kamiah. While the making of such a test in this region is justified from geologic considerations, the cost would probably be far greater than the best results to be hoped for would warrant. The test well should be carried to a depth of at least 3,000 feet, unless successful results are attained at a less depth, or the rocks which underlie the Columbia River lava are reached; and the expense would probably be greater than the utilization of the water for irrigation purposes would justify. Seemingly, it is only for the supply of towns of considerable size that such an experiment as has been suggested should be made.

A portion of the Camas-Kamiah Basin adjacent to the base of Mount

Idaho, embracing an area of about 200 square miles, has a gentle slope northward, and is uncut by canyons more than one or two hundred feet deep. Beneath this area there are porous beds at no great depth, as is shown in part in the canyon walls and in part by borings that have been made. While some of these porous beds are cut by the shallow canyons, others pass under them and should furnish water under pressure. The principal hope of obtaining flowing water in this region is based on two principles: (1) That the pervious beds composed of unconsolidated *débris* swept out from the mountains and covered in part by lava may change and become impervious at a distance from the source of supply. (When this happens, and the bed is inclined and overlain and underlain by sheets of impervious material, a well put down in its coarser portion should yield a surface flow.) (2) That the flow of water through an inclined porous bed having impervious beds above and below is retarded by friction and may yield a surface flow at certain localities, although it is cut by a canyon at a distance.

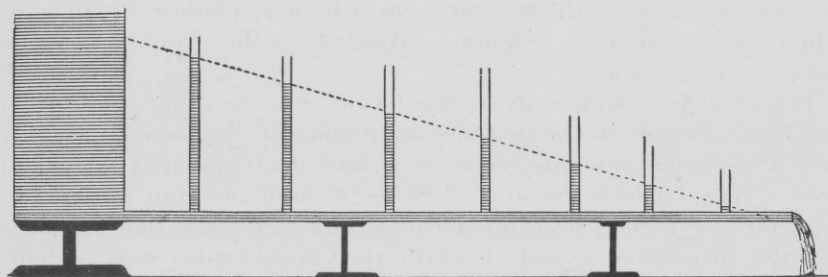


FIG. 9.—Diagram of apparatus illustrating the declivity of head of liquids flowing from a reservoir.

The first of these principles is self-evident, but the second may perhaps require further explanation.

That water confined in an inclined porous bed may, owing to the friction of flow, rise to the surface in case wells are drilled midway down its slope, is proved by an experiment such as is illustrated in fig. 9.

In the region about Denver, in the southern portion of the Camas Prairie and probably extending as far westward as Cottonwood, the slope of the strata is northwestward at a low angle, or away from the bold escarpment known as Mount Idaho. This mountain was not visited during the *réconnaissance* which forms the basis of this report, but, judging from its topography and from observations made by others, it no doubt is composed of rocks of older date than the Columbia River lava, and forms a portion of the boundary of that formation. *Débris* from this ancient upland swept down upon the Columbia River lava at various times during the intervals between the eruptions which gave origin to its numerous sheets, and should occur and be favorably situated to be charged with water. That such beds are

present between the sheets of lava has already been shown. They may be expected to be thickest adjacent to the mountain from which the débris composing them was derived, and to thin out and become finer in texture toward the center of the basin on the inward-sloping side of which they occur. This indicates that the two principles in reference to artesian conditions may there find application, and the facts furnished by certain wells that have been drilled seem to bear out these conclusions.

Wells at Denver.—Such facts as it has been possible to glean concerning the several wells put down on the Camas Prairie, principally at Denver and vicinity, are here presented. In most instances the information has been furnished from memory by persons who were present when the wells were drilled.

A well drilled on the farm of N. Nelson, $1\frac{1}{4}$ miles east of Cottonwood, in 1899 passed through the following strata:

Section at well on farm of N. Nelson.

	Feet.
Surface soil and subsoil containing fragments of basalt.....	40
Soft basalt	26
Gravel, soft, easy to drill	52
Total depth	118

Work was discontinued on account of an accident to the drilling rig. Water was obtained in the gravel and rose to within 66 feet of the surface, but did not overflow. The well does not seem to have been properly cased.

At Denver five drill holes have been put down, the records of which, so far as it is now practicable to obtain them, are as follows:

Well No. 1: Near Parker's mill; drilled in 1893; total depth, 202 feet; hard rock not reported; water rose gradually from near the bottom to within 90 feet of the surface; supply large; pumped by means of windmill and steam power, and used for boilers in the mill; wooden casing for first 100 feet.

Well No. 2: Under Parker's mill; distant about 150 feet from well No. 1; drilled in 1895-96; no solid rock reached; the first 110 feet in soil and subsoil containing blocks of basalt; sand and clay containing white pebbles (quartz) at 100 feet; at 140 feet the sides caved in and many tons of sand were taken out; water rises to within 90 feet of the surface; supply small; an abundance of water reached at 205 feet, but could not be utilized, owing to the caving of the walls; well has a wooden casing down to a depth of 140 feet, and a galvanized-iron tube within it to a depth of 90 feet.

Well No. 3: In the central part of the town, about a half mile from well No. 1 and at an elevation 50 to 60 feet greater; total depth, 235 feet; a little water obtained at 100 feet, a large supply at 200 feet; the water rises to within 100 feet of the surface; iron casing for a short distance from the surface, to retain loose material, and a 2 $\frac{1}{2}$ -inch iron pipe within, for pumping, which reaches a depth of about 200 feet; water now pumped by steam power and windmill for town use.

Well No. 4: In the northern portion of the town, about a half mile from well No. 3 and 20 feet higher; said to have been drilled entirely in loose material; total depth, 325 feet; water rose to within 90 feet of the surface; not used.

Well No. 5: In southeastern portion of the town: was abandoned at a depth of 100 feet.

Within a radius of about 3 miles of Denver and to the south of the town four other wells are said to have been put down to depths varying from 100 to 220 feet, but not one of them furnishes flowing water. One of them, on the farm of C. B. Kanos, was sunk to a depth of 200 feet in solid basalt. Another, $2\frac{1}{2}$ miles southeast of Denver, excavated mostly with pick and shovel, according to the statements of Mr. W. H. Zumwalt, passed through the following strata:

Section $2\frac{1}{2}$ miles southeast of Denver.

	Feet.
Soil and subsoil.....	16
Rock (basalt)	31
Soft material of various colors	93
Total depth.....	140

Plenty of water was obtained at 136 feet, and maintains a depth of 10 feet; used for farm purposes. Another well, $1\frac{1}{2}$ miles south of Denver, on the farm of Isaac Zehner, passed through soil and subsoil to a depth of 80 feet, and then through 140 feet of basalt. The total depth of the well is 220 feet. Water was reached at 200 feet; did not rise; is used for farm purposes.

The great variations in the nature of the rocks passed through in the sinking of the wells in and about Denver show that the surface portion of the formations undergoes marked changes within short distances. In the town wells no solid basalt was encountered, while $2\frac{1}{2}$ miles to the southeast, on the Kanos farm, basalt with a thickness of 31 feet was reached at only 16 feet beneath the surface. It overlies soft beds of variegated colors, such as presented by the sedimentary beds beneath the upper lava sheet on Grande Ronde River and at other localities. The reason for these variations has not been thoroughly determined. The facts in hand seem to indicate, however, that the surface sheet of basalt at Denver has been eroded away or decayed, while in neighboring localities it still remains and is but little changed. The explanation offered on a preceding page—the rough topography of the level plateaus—may apply here. That is, the surface sheet of basalt at Denver was cut by stream channels during a period of more active erosion than is now in progress, the surface evidence of which has been obliterated by subsequent movements in the loose superficial material. The mountains, however, are only 10 or 12 miles distant, and alluvial material may have been deposited on the previously eroded and weathered surface sheets of basalt, thus again concealing the changes previously produced in its relief. Sufficient time was not available to test these suggested hypotheses in the field.

The wells thus far put down on the Camas Prairie, although showing that water under pressure exists in certain layers, do not furnish a fair test of the artesian conditions. None of the wells are properly cased; but the fact that in those at Denver the water rose more than 100 feet above the level of the point where it was first reached gives evidence of true artesian conditions. It is probable that if these wells should be properly cased a surface flow would be obtained.

The structure of the rocks beneath the Camas Prairie and what is known concerning the texture of the beds, as well as the information furnished by the wells that have been drilled, favor obtaining flowing water at a depth of a few hundred feet in the region about Grangeville, Denver, and Cottonwood.

SUGGESTIONS AND RECOMMENDATIONS.

For the benefit of the people in the Nez Perce region who are directly interested in the search for water, and to whom the experience in well drilling gained elsewhere is not easily accessible, the restatement of a few well-known principles bearing on the general subject of artesian wells may, perhaps, be welcome. The following suggestions have been taken principally from a paper by Prof. T. C. Chamberlin, the title of which, together with references to other treatises on the same subject which may profitably be studied by well drillers, is given in the list of references presented in the bibliography on page 130.

Attention has already been called to the fact that none of the wells in the two artesian basins described are properly cased, and in several instances no attempt has been made to insert the necessary pipes through which the water can rise. As the material passed through, especially near the top, is open and porous, it would be a surprise in most cases if water should rise through it to the surface. The importance of casing wells can not be overestimated, for it is no more reasonable to suppose that water can rise through a hole drilled in open and porous material than that it can rise to the third story of a house if the supply pipe in the basement is full of holes.

The usual method of preventing the escape of water on the outside of the casing of an artesian well is to surround the casing just above the water-bearing stratum with a bag made of leather or rawhide and filled with dry flaxseed. The flaxseed absorbs the water and swells and expands the bag so as to shut off the water from the space outside the pipe. The method of attaching the bag is shown in fig. 10.

Another method for obtaining the same result by means of rubber disks is described and illustrated by Chamberlin in the article referred to.

By means of a seed bag tests can be made which will reveal the most desirable position for the lower end of the casing. In this con-

nection the following quotation is made from the paper by Chamberlin:

The water may rise from the bottom to some higher portion of a well, and there find escape by passing laterally through the upper strata, and fail to overflow. It is a matter of some practical moment, therefore, to know when a stream is struck which may yield a flow at the surface when put under proper control: (1) Such a stream usually discovers itself by a rise of water in the well, but this is not always the case. (2) Some influence on the action of the drill is liable to be felt, which may arouse suspicion. (3) In any instances of a strong flow, the drillings are apt to be carried away, so that when the sand-pump fails to bring these up, or brings only coarser material, there is good reason to believe that a stream has been struck and the proper test should be made. It is ordinarily desirable to test the capacity of any stratum which gives any of these or other indications, before sinking to a lower one. It is advisable to make provision in the contract for such tests, since it is not always to the interest of the driller, once his machinery is set up and well at work, to stop at the more limited depth. The capabilities of the flow may be tested by the use of a tube and seed-bag, or by rubber packing, as explained above.

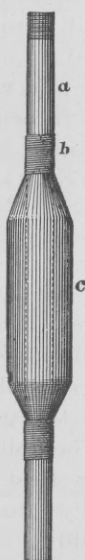


FIG. 10.—Seed-bag packing around well casing. *a*, Delivery tube leading to the surface of the well and terminating below the seed bag; *c*, leather bag filled with dry flaxseed; *b*, marline wrappings to secure the ends of the seed bag. (After Chamberlin.)

made, and the result will indicate their combined capacity; or, if both heads are at least as high as the surface at the well, the test may be accepted. But suppose that the bed A has been cut into by erosion, or been reached by crevices, or is otherwise defective, while the other, B, remains intact and bears an elevated fountain-head. Under these conditions the water may flow from B through the bore into A, and escape laterally through it, as illustrated in the figure. Now, in this case the result may be either simply negative or positively false and misleading. If the lateral leakage through the stratum A effectually disposed of the flow from B, and there was no leakage in the upper portion of the well, the water in the test-tube would stand during the test at essentially the same height as before, and the result would be negative, merely failing to indicate a possibility that really existed. If, on the other hand, there was lateral leakage through the upper strata as well as through A, neither alone being quite competent to dispose of the flow from B, then the introduction of the test-pipe would cut off the upper leakage, leaving the bed A unable

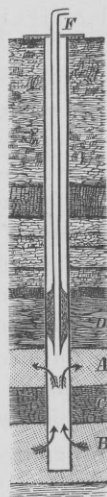


FIG. 11.—Section of well, illustrating a negative test for water under pressure. (After Chamberlin.)

to dispose of the entire flow. In this case there would be a rise of water in the tube, and, possibly, a flow. The mischievousness of a test of this sort lies in the fact that it appears to be a true test, because it shows some result, while in reality it is false and misleading. The true test in this case can only be made by placing the packing between the porous beds A and B.

Take another instance where two porous beds, as A and B, figure [12], have been traversed. Let the packing be placed between these. Then (1) if A equals B in productive capacity, water will stand at the same height within and without the test-pipe *if there is no leakage in the upper beds*. (2) If the failure to flow was due to such leakage, then a flow will result from B, but the additional flow which might be secured from A is lost (see figure). (3) If A has a greater head than B, and if there is no loss above, the water in the test pipe will actually be lower than that outside, as illustrated in figure [13]. This may be said to be an *inverted test*, and is less misleading than the false and negative tests, since it plainly indicates an error of manipulation. I have known such a case of reduced head as the result of an attempted test. (4) If, however, there is in this case considerable lateral waste in the upper strata, the valuable flow from A will be lost, just as before the test was made, while B may give a rise in the tube, or even a flow, which would foster the impression that a fair test had been made,

while in reality the greater flow has been lost. (5) A gives a feeblor flow than B, but has an equal head, the test will fail of being completely satisfactory only in excluding the feeblor flow from A. (6) If, however, A has a lower head, and is a possible means of escape for the flowage from B, then the packing has been placed at the right point, and the test gives the best results.

In still another case, let A and B represent porous beds (figure [14]) the lower of which is so conditioned as to drain the upper one by virtue of a lower outcrop, in the manner previously explained and illustrated in figures [13 and 14].

(1) First, if the drainage-loss below is not complete, and if the packing is placed above A, as shown in figure [14], I, the result will be negative, if there is no leakage in the upper strata. (2) Should there be considerable loss there it will be cut off by the tube and packing, and some rise in the tube will be the result in most cases. In either instance the result is misleading, particularly in the last, because the small rise of the water is apt to allay any suspicion as to the effectiveness of the test. The real fact, however, remains that the flow from the productive stratum is mainly lost below. (3) Suppose that the packing is located between A and B, as in figure [14], II, it will then shut off the flow from A, while that in B, because of a lower outlet, will fail to flow. Now, if there is

opportunity for lateral leakage in the upper strata the water from A will rise in the well *outside* of the test-pipe and pass off into these open upper beds. (4) But if no such opportunity is afforded it may rise to the surface and overflow *outside* of the test-pipe, while the water within the test-pipe will probably be found to be lower than

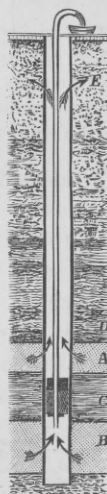


FIG. 12.—Section of well, showing a partial and misleading test for water under pressure. (After Chamberlin.)

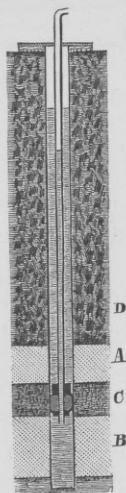


FIG. 13.—Section of well, illustrating an inverted test for water under pressure. (After Chamberlin.)

before the test was made. The proper method of testing wells known or suspected to present these conditions is to sink a simple bag of seed or other obstruction to a point in the impervious stratum between A and B, which, when it tightens in its place, will shut off the flow below. Then a tube with packing sunk to a point above A will effectually cut off all leakage in the upper strata, and the full capacity of the water-bed A will be tested.

These examples, while not exhaustive of possible cases, illustrate the nature of defective tests and the deceptive conclusions liable to be drawn from them. The remedy is manifest. Test each water-bearing stratum as it is encountered, or else vary the final tests so as effectually to exclude all liabilities to error.

To test the pressure of the water in an artesian well and thus learn the *artesian head*, a tube open at its upper extremity may be attached to the top of the casing, or of a pipe inserted in the well and provided with a seed bag at the proper place, and carried up until the water no longer overflows. For this purpose a rubber hose pipe can frequently be used to advantage. The height to which the water will rise in the tube will show the horizon below which other wells in the same artesian basin may be expected to yield a surface flow. The

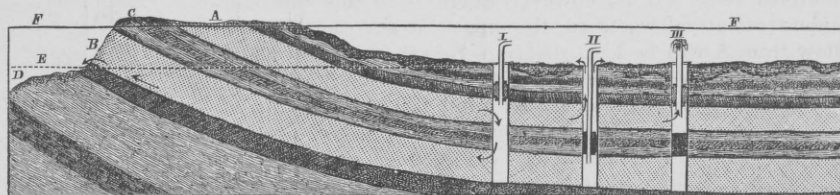


FIG. 14.—Section showing one correct and two erroneous tests for water under pressure. These wells are assumed to be independent of one another, and are placed together on the diagram merely for convenience. (After Chamberlin.)

same result can be reached by attaching an ordinary steam gage to the top of the casing and reading the pressure. Each pound of pressure per square inch will be equal to a rise of water in an open tube to the height of 2.31 feet.

The writer wishes to emphasize a few principles which evidently are not fully appreciated by all of those interested in the drilled wells of the Nez Perce region.

(1) All wells should be thoroughly tested in one or more of the ways just described, to ascertain the pressure of the water at various horizons, and if sufficient pressure is discovered at any horizon to force the water to the surface the well above that point should be effectively cased.

(2) When flowing water is obtained the well should be *securely closed at all times when the water is not being used*. The reason for this is that every flowing well is an opening into a reservoir which is *not* inexhaustible.

(3) Wells which for any reason are abandoned should be closed just above the water-bearing stratum, so as to prevent leakage into other porous layers or through fissures. This can be accomplished by

lowering a closely fitting plug of wood, about 10 feet in length, to the proper horizon. The swelling of the wood on absorbing the water will close the opening. Possibly a more satisfactory way would be to fill the boring with Portland cement. This matter is so important that it should be made a law applicable to every artesian basin. To demonstrate the importance of this measure it is but necessary to consider the wells in Tammany Hollow and at Denver, which either are not cased or are imperfectly cased and in which water rises to a definite horizon and in some instances remains at that level even when active pumping has been maintained for a long time. Such wells are in reality flowing wells, although the escape is subterranean, and are in each case reducing the pressure in the supplying stratum.

ECONOMIC GEOLOGY.

From the hasty reconnaissance on which this report is based it is not safe to venture far in reference to the economic value of the mineral resources of the region. A few notes, however, in this connection may be of some service when a more thorough geologic survey is undertaken.

BUILDING STONE.

A fine-grained, gray granite (diorite) of excellent quality occurs in practically unlimited quantity on Snake River, about 6 or 8 miles above the mouth of Grande Ronde River, and has been quarried in a small way at two or three localities. The excavations thus far made are not sufficient to demonstrate the full value of the quarries, but they indicate that large-sized blocks of homogeneous stone can probably be obtained. The localities referred to are on each side of the river, close to its margin; they are favorably located in reference to water transportation, and it is safe to predict that this beautiful granite will furnish the basis for an extensive industry in the near future.

A somewhat coarse-grained diorite, or what in commercial circles would be termed granite, occurs on Mission Creek, where it cuts through Craig Mountain, and also near Kippen. Judging from the outcrop, a good building stone might be obtained at these localities should a demand occur which would counterbalance the difficulties of transportation.

Diorite similar to that on Mission Creek occurs in vast quantities in Clearwater Canyon, from near Orofino to above Kamiah, and, as shown in several railroad cuts, an unlimited quantity of excellent stone for all kinds of rough masonry can easily be obtained. At all of the localities examined the rock is much broken by joints and is traversed by veins, so that uniform blocks of large size could not economically be quarried. This region demands careful study, however, for the conditions pertaining to transportation are favorable, and rock of uniform

grade suitable for architectural and monumental purposes is likely to be discovered.

True granite is abundant in the central part of the Bitterroot Mountains, but its distance from all lines of transportation makes it at present of no commercial value.

Limestone occurs in great quantities on the borders of Snake River, from 1 to 3 miles above the mouth of Grande Ronde River, and also about 8 miles farther upstream. The value of this stone for marble has not been tested, but it certainly merits careful study. An analysis of an average sample of the rock is given in the first column of the subjoined table of analyses of limestone, which shows it to be of exceptional purity.

Limestone outcrops beneath the Columbia River lava on the right bank of Mission Creek, about a half mile above where it emerges from the deeper portion of its canyon in the Craig Mountain uplift, and also in a gulch about 1 mile to the west. Along Mission Creek, for a distance of approximately 300 feet, the limestone is admirably exposed in the precipitous canyon wall to a height of 500 feet. It is in general a hard, grayish blue rock, containing a few obscure fossils. The strike of the beds is N. 50° E. (magnetic), and the dip is eastward at an angle of from 80 to 85 degrees. Formerly it was burned in kilns, which still remain, and it is said to have yielded a good lime. The value of the stone as marble can scarcely be judged from the weathered outcrops, but its dark color would probably make the demand for it small, even if on quarrying it is found sufficiently massive to be taken out in blocks of the desired size. An analysis of a typical sample of this rock is presented in the subjoined table, which shows that, like the similar limestone in Snake River Canyon, it is of exceptional purity and will make an excellent lime, and it is all that could be desired in the production of Portland cement or for use in the manufacture of beet sugar, etc.

On the left bank of Mission Creek, opposite the outcrop just described, a landslide has brought down basalt from above and concealed the limestone which normally should appear there. Visitors to this locality will no doubt be interested in observing the manner in which the landslide has caused the stream to be turned aside from a formerly more direct course and made to cut into its right bank, thus removing some of the débris that once concealed a portion of the limestone and making it more available for quarrying. The surface of the fallen mass forms an irregular terrace at an elevation of about 500 feet above the stream. The surface of this terrace presents a good illustration, on a small scale, of landslide topography.

Limestone occurs also at Orofino and at three or four localities on Orofino Creek within the first mile above its mouth, as well as on the southern side of Clearwater River about a half mile below Orofino. At each of these localities the well-defined beds are associated with

schist; they strike about north-south, and stand nearly vertical. The limestone has been metamorphosed, and is now mostly a coarsely crystalline marble, varying in color from white to gray. It is susceptible of a high polish, and should find a ready market for building and monumental purposes, provided it can be had in blocks of the desired size. It is favorably situated for quarrying, being close to the Northern Pacific Railroad. The surface is considerably shattered, but is not deeply weathered. Whether it is sufficiently massive at a moderate depth below the surface to be of value, can only be determined by trial. A sample of the nearly white, coarse-grained marble from Orofino has been analyzed, with the results shown in the third column of the following table:

Analyses of limestones from Nez Perce County, Idaho.

[W. F. Hillebrand and George Steiger, analysts.]

Constituent.	Snake River Canyon.	Mission Creek.	Orofino.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica (SiO ₂) and insoluble materials <i>a</i>	0.39	1.19 (Silica=1.08)	0.64 (Silica=0.37)
Iron, manganese, and aluminum oxides.....	0.10	0.19	0.12
Calcium oxide (CaO).....	55.34	54.75	51.96
Magnesium oxide (MgO).....	0.10	0.51	3.05
Carbon dioxide (CO ₂), calculated.....	43.59	43.50	44.08
Organic matter.....	-----	Strong trace.	Trace.
	-----	100.14	99.85
Calcium carbonate (CaCO ₃) <i>b</i>	98.83	97.69	92.71
Magnesium carbonate (MgCO ₃) <i>b</i>	0.21	1.07	6.38

a The insoluble portions in analyses Nos. 2 and 3 contained a trace of titanium oxide (TiO₂).

b The amount of carbonates calculated are a trifle too high if the silica found was originally in combination with some of the dissolved lime and magnesia.

The analysis of Snake River limestone is by Steiger; the others are by Hillebrand.

The limestones from Snake River Canyon and Mission Creek are exceptionally pure and are suitable for use in the manufacture of Portland cement, in the beet-sugar industry, etc. The limestone at Orofino evidently would make a good lime if properly calcined, but it is not desirable for the other purposes mentioned, on account of the magnesium present. There are, however, several beds of limestone near Orofino, a careful study of each of which would very likely reveal the presence of material as rich in calcium carbonate and as free from impurities as the limestone from Mission Creek and Snake River Canyon.

Basalt (lava) is everywhere abundant in the Nez Perce region to the west of the foothills of the Bitterroot Mountains, and generally throughout central and eastern Washington and Oregon. Its somber color makes it objectionable for most architectural purposes, except for the foundations of buildings, bridges, etc., but in many cities similar rock has been used for entire buildings. Its chief use should be for

road material, to which purpose it is well adapted.* It is hoped that the time will soon come when the poor roads of the region occupied by the Columbia River lava will be improved by macadamizing them.

The volcanic dust interbedded with the Columbia River lava on Captain John and Asotin creeks has been used for the walls of a bank building in Lewiston, and has the advantage of being easily worked and of a desirable color. It is doubtful, however, whether the use of this stone for outside walls should be encouraged; but for interior walls, especially of fireproof buildings, it has decided advantages over most other stones. It would be interesting to experiment with this dust, in connection with Portland cement, in the manufacture of artificial stone, and also to test its desirability as an ingredient of friction soap. The finer grades, when well sifted, make a good polishing powder.

Slate of a pleasing reddish color, of easy cleavage, and, so far as can be judged from natural exposures, of good quality, occurs on the eastern side of Cottonwood Butte, and is well located for quarrying. This material should be thoroughly tested as soon as transportation facilities admit of its being put on the market, to ascertain whether sheets of the desired size can be obtained.

LIGNITE.

In the sedimentary beds interstratified with the Columbia River lava lignite has been discovered at several localities. On the southern side of Clearwater River a half mile below Orofino openings have been made in the side of the canyon, on the farm of F. M. Holt, at an elevation of about 200 feet above the river, which reveal the following section:

Section on Clearwater River one-half mile below Orofino.

	Feet.
Talus, from slopes above	
Sandstone, coarse	2.0
Slate, fine, sandy	0.8
Lignite, with branches of trees	0.2 to 0.5
Sandstone	2.5
Lignite	0.2 to 0.4
Sandstone	5.0
Lignite	1.7
Sandstone, bottom not seen	1.0
Talus to the river bank	

The beds are well exposed in the openings that have been made, one of them being a tunnel about 40 feet in length, but the material is part of a series of landslides, and the true position of the lignite should be sought about 500 feet higher than where it is now to be seen. The prospecting that has been done serves to indicate that a bed of lignite exists beneath the neighboring plateau, but there is no

reason for doing further work at the locality where openings have already been made.

Lignite is reported to occur at several localities on Orofino Creek (all of it probably belonging to approximately the same bed), within a distance of several miles in the middle portion of its course. The only one of these outcrops that was examined by the writer is situated on the immediate banks and in the bed of the creek about 15 miles above its mouth (sec. 12, T. 36, R. 4), but is not in place. As already explained, vast numbers of landslides have occurred on each side of the canyon of Orofino Creek throughout its entire length in the Columbia River lava. The number and large size of these slides is evidence of the presence of a thick layer of soft material beneath the upper sheet (or sheets) of the lava which forms the surface of the adjacent plateaus. On the left bank of the creek, at the locality referred to, and partially submerged, the following section is exposed, the dip being south at an angle of 30 degrees and the strike about east-west, or with the course of the stream:

Section on Orofino Creek about 15 miles above mouth.

	Inches.
Sandstone, gray, with fossil leaves	12.0
Lignite	20.0
Clay parting	2.5
Sandstone, base not exposed	6.0

These outcrops can be followed along the bank of the creek and in its bottom for a distance of 60 to 70 feet. Near the upstream end of this natural exposure, on the north side of the creek and at the water's edge during low-water stages, a prospect shaft about 15 feet deep has been opened. In this shaft the strata where first met, beneath a foot or two of surface débris, are nearly vertical, but below they dip northward and soon flatten, until the inclination is about 50 degrees. The lignite is 27 inches thick, and has fine micaceous clay on its southern side and a coarse sandstone on its northern side. The lignite-bearing formation on the two sides of the creek is a portion of a sharp upward fold or anticline, which is broken along its crest, where the creek now flows. This fold is obviously due to the weight of the landslides on each side, and is not a structural feature of the beds in place.

The true position of the lignite in the canyon walls is not known, but should be looked for at an elevation of between 400 and 600 feet above the creek. The lignite-bearing rocks no doubt underlie a wide extent of the adjacent plateaus.

The most satisfactory way in which to prospect for the lignite would be to put down drill holes on the plateaus, where the formations are undisturbed, unless a locality can be found along the borders of Orofino Canyon or its branches where the all-prevailing talus and displaced masses leave the sedimentary beds exposed.

Lignite is reported to occur at several localities in the bed of Orofino Creek above the exposure just described. It is doubtful, however, whether any of these outcrops are in place, but they should indicate the value of the deposits beneath the adjacent plateaus. It is also reported to exist at several places in Little Canyon, to the south of Orofino. One of these outcrops, near Russel, which was examined by the writer, is at the bottom of the canyon, which there is 800 feet deep and has precipitous walls composed of horizontally bedded lava sheets. Throughout the portion of the canyon seen there is a notable absence of conspicuous landslides, from which fact, and from the abundant exposures of the edges of lava sheets, it is to be inferred that sedimentary beds at a higher level than those in the bottom of the canyon, described below, are either absent or are of small thickness. On each side of the canyon at the locality referred to near Russel, where a lateral canyon joins it from the eastward, and on the border of the tributary brook, the following section was exposed by a recent excavation:

Section in Little Canyon, near Russel, Idaho.

	Inches.
Talus, fallen from above.....	75.0
Carbonaceous shale, apparently altered by heat.....	41.0
Parting of white laminated shale composed in part of volcanic dust.....	1.0
Black carbonaceous shale.....	2.5
White "shale".....	1.5
Black carbonaceous shale.....	6.0
White laminated shale ¹	10.0
Coarse sandstone with fragments of shale, base not exposed.....	36.0
Total, about.....	feet.. 14.5

The carbonaceous shale reported in the section, although probably mistaken for lignite, or "coal," by the parties who prospected it, is much too earthy to pass for that material, and is probably of no economic value. Although no lignite was seen by the writer, and none has certainly been discovered in Little Canyon, the presence of carbonaceous shale, sandstone, etc., at about the horizon at which the lignite near Orofino probably belongs, is sufficient encouragement to warrant the sinking of a prospecting shaft at the locality described. Equally favorable sites for prospecting no doubt occur at other places in Little Canyon, and probably also in Big Canyon. In making such a test as suggested, the talus should be cleared away from the base of the cliffs, so as to expose the contact of the sedimentary beds with the basalt above, and a shaft be sunk at a locality where it would not be

¹ The peculiar, evenly laminated white "shale" is composed in part of volcanic dust, and is crossed by irregular and in places vertical fissures which are filled with a dark material, probably once a soft mud, containing fragments of both sedimentary and volcanic origin. Similar debris-filled fissures were observed in the beds of fine white volcanic dust exposed in Potlatch Canyon.

flooded during high water. The shaft should be continued through the sedimentary beds and at least a few feet into the basalt beneath. A single shaft, however, would not be sufficient to determine the value of the field over a large area, as it is possible that the lignite occurs in more or less detached lenticular bodies, each one representing the vegetable matter accumulated in an old swamp.

Lignite is reported to occur at a few other localities in the lava-covered portion of Nez Perce County, as, for example, on Captain John Creek; but these places were not visited during the reconnaissance. It has also been discovered on the southern side of the Blue Hills in Washington—on the slopes leading down to Grande Ronde River, about 20 miles from the mouth of that river. The openings in lignite which have been made are on S. P. McNeil's land and neighboring ranches, but other outcrops are said to occur on each side of the canyon in this region throughout a distance of several miles. The northern side of the canyon, as already described, is encumbered with landslides, and a very large part of the secondary topographic features are due to this cause. The marked prevalence of landslides and the large size of some of the displaced rock masses are strong evidence of the presence of thick layers of soft material between the conspicuous lava sheets. The indications of the presence of sedimentary beds which are furnished by the topography are confirmed by known outcrops of sandstone, lignite, clay, volcanic dust, etc. All of the exposures of lignite observed by the writer are on or near Mr. McNeil's ranch. At one locality a tunnel about 125 feet long has been excavated, all of it in lignite. Near the inner end of this tunnel a thickness of 9 feet of lignite, practically without partings, was measured, but neither its upper nor lower surface was exposed.¹ Well within the tunnel the dip is northward at an angle of 2 to 2½ degrees. In another excavation, about 2 miles east of the one just referred to, a thickness of 16 feet of lignite is reported to occur, and there seems no reason to doubt the accuracy of the observation.

All of the facts learned by the writer pertaining to the lignite in the canyon of Grande Ronde River are in harmony with the idea that the openings thus far made in it are in landslides, and that the true position of the beds, or where they occur in place, is 200 or 300 feet below the summit of the canyon walls. From the facts in hand it seems evident that the thickness of the lignite where openings have been made in it is abnormal and does not represent the thickness that will be found where the beds are discovered in place. As is well known, a mass of rock descending in a landslide accumulates material beneath it, along its lower margin, and on coming to rest almost invariably has a back-

¹ The writer has been informed by Mr. E. W. Barnes, of Portland, Oregon, under date of January 9, 1901, that since the visit to the tunnel during the reconnaissance it has been extended about 25 feet, and a winze has been sunk at its end to a depth of 25 feet from the roof of the tunnel, all in lignite, with the exception of a few thin partings. The writer understands, however, that even these recent excavations failed to reveal the full thickness of the lignite.

ward dip, or is inclined downward toward the cliff from which it broke away. In the tunnel referred to the dip is northward, but the downward inclination of the rocks in place in that region should be southward, as previously explained. The lignite and its accompanying beds of sedimentary material and volcanic dust appear to have been sheared and overthrust, owing to the weight and motion of the overlying basalt, which descended with them. For this reason they exhibit a greater thickness than should be assigned to them in estimating their commercial value.

While the bodies of lignite in some of the landslides are no doubt of sufficient size to be of value, no great areas are to be expected. The present excavations are sufficient to demonstrate the quality of the material so far as the beds exposed are concerned, and if this is found to be satisfactory, future prospecting, with the view to discovering the beds in place, is justifiable.¹

The discovery of the lignite in place should not be a difficult matter. After traveling over the slopes where landslides are prevalent, and becoming familiar with the characteristic features in the relief produced by them, a wide-reaching view of the canyon walls, such as can be obtained from almost any eminence in the region, will enable one to determine the localities where the rocks are still in place. These areas will usually be found to be bounded by cliffs from which landslides have fallen, and the removal from the bases of these cliffs of the all-prevailing surface *débris* should reveal the sedimentary beds carrying the lignite. A shaft sunk at the margin of such an escarpment should be carried down to the next sheet of basalt, and would reveal such lignite beds as may be present. The test should not be abandoned in case a lignite seam is found which is too thin to be worked to advantage, for other seams may occur below it. The lignite layers no doubt vary in thickness from place to place, and a thin seam discovered in one shaft may be found to thicken at a neighboring locality. Probably the localities where the lignite can most

¹ Mr. E. W. Barnes, of Portland, Oregon, has kindly furnished the following analyses of samples of lignite from the locality described, which were collected by himself. The analyses were made at the Montana Metallurgical Works, Portland, Oregon, J. T. Gove, manager.

Analyses of lignite from Grande Ronde River, Washington.

Constituent.	Sample No. 1.	Sample No. 2.
	<i>Per cent.</i>	<i>Per cent.</i>
Moisture	20.50	6.50
Volatile combustible matter	40.75	38.50
Fixed carbon	31.25	42.00
Ash	7.50	13.00
Total	100.00	100.00

If sample No. 1 fairly represents the beds described, it is evident they are of commercial importance. It is desirable, however, to have tests made of the heating properties of the lignite on a large scale before forming a positive opinion as to its value.

easily be found in place are in the cliffs on the south side of the river, 200 or 300 feet below their summits; but a mine developed there will have to follow a seam which is dipping southward, or away from the mouth of a tunnel begun at the outerop, and in general would be more difficult to drain than a mine on the north side of the river, where the dip would favor both drainage and the removal of the lignite. The most favorable location on the south side of the river would be near the head of a lateral canyon, for at such a locality a tunnel could be run approximately parallel with the strike of the beds, thus insuring drainage for lateral tunnels which might be directed up the slope.

In most instances the lignite retains its woody structure, and looks very like the wood derived from modern peat swamps. Its color is black when wet, and except when composed largely of trunks and branches of trees is nearly black when dry. It exfoliates and crumbles rapidly when exposed to the air. The woody portions when dry have a rich brown color and clearly show their structure. It can not be termed coal, and is apparently a rather poor quality of lignite. These statements apply to the lignite, so far as the writer has seen it, at all of the openings made in it in the Nez Perce region, except the one on Orofino Creek, where kernels and irregular masses, an inch or more across, of yellow resin but little altered from its original condition are conspicuous in certain portions of the deposit. Small specimens of lignite "float," said to have been found in the canyon of the North Fork of Clearwater River in the vicinity of Elk Creek, and other similar fragments from Orofino Creek are jet black in color, and evidently are of much better quality than any of the material thus far obtained at the localities described.

GOLD, SILVER, AND COPPER.

To the reader who is not familiar with the mineral resources of the Nez Perce region it may be of interest to learn that the crystalline rocks of older date than the Columbia River lava are quite generally ore bearing. These rocks in many instances are metamorphic in character; that is, they consist of either sedimentary or igneous material that has been greatly altered by heat and pressure and by movements which have caused it to become sheared and assume a schistose structure. Besides these changes there have been great intrusions of molten magmas, either into fissures, as in the formation of the numerous dikes, or of a regional character, as the intrusion of granite, diorite, etc., into the earth's crust from great depths below the surface. Where either the metamorphic or plutonic rocks are exposed at the surface it is manifest there has been deep erosion. The thickness of rock removed has not been measured, but may safely be estimated at several thousand feet. The rocks which once were deeply buried are frequently traversed by veins in which more or less metallic material,

in the form of free gold or of ores of silver, copper, etc., has been deposited from the heated waters which percolated through them.

In general the rocks exposed beneath the Columbia River lava in the canyons of Snake, Salmon, and Clearwater rivers are such as are looked to for deposits of gold, silver, copper, and many other ores and minerals. The prediction which a geologist would be led to make from the general character of these rocks is that they will be found to contain the precious metals, which is verified by the discovery of gold and of ores of silver and copper in what are reported to be rich deposits. Several gold mines are being worked to the east of the margin of the Columbia River lava, and hundreds of promising prospects are reported in the same rugged country. The most productive gold-bearing quartz mines in the region shown on the map forming Pl. II are in its northeastern portion, in the Mascot Hills; but similar conditions exist as far south as Mount Idaho. Just what the future of these gold mines will be no one can tell, but the superficial examination which the writer was enabled to make failed to indicate great possibilities. The rocks contain numerous small gash veins, consisting of quartz which has been deposited from solution and containing mineral matter derived from the adjacent country rock; but they did not reveal the presence of any true lodes or fissure veins. The small veins are frequently rich and serve to stimulate prospecting, but the chances of discovering a bonanza are meager.

The great amount of erosion referred to, which has led to the exposure of the vein-bearing rocks now occupying the surface, was accomplished by the crumbling and decay of a vast amount of rock similar to that now in sight. The removal of this material by streams resulted in its being assorted, the gold which it contained being concentrated on their beds. In this manner the bottoms of all of the streams flowing away from the mountains of old crystalline rock became charged with alluvial or placer gold. Gold is now obtained by washing the gravel along Snake, Salmon, and Clearwater rivers, and the total amount collected each year is considerable. The gold along the main streams and in the gravel forming their abandoned flood plains is nearly all fine, so fine, in fact, that in most instances a portion only of it can be saved by any known method of placer mining. Along some of the smaller streams tributary to Clearwater River rich placers of coarse gold have been discovered. The most productive of these are just above the margin of the Columbia River lava; but they have now been worked out and abandoned. Rich copper ores are obtained in the side of the canyon of Snake River above the mouth of Grande Ronde River, and important developments in that field are to be expected.

To the reader who has labored for years with pick and shovel in searching for treasures in the Nez Perce region the writer has but one suggestion to offer. In a preceding paragraph attention was

directed to the well-known process by which rocks are disintegrated and the gold which they contain is concentrated in stream beds. As this process was in action long before the coming to the surface of the Columbia River lava, it is evident that the stream channels beneath the lava should contain gold. The exceedingly rich placers on Cow, Reid, and other creeks on the border of the Mascot Hills occurred in gulches just above the margin of the lava, and but little gold has been obtained from above the lava itself. One reason for this is that the streams from the uplands of old crystalline rock experience a sudden change in gradient on meeting the level lava sheets, being swift in the older portions of their channels and sluggish where they flow across the lava to the head of a canyon cut in it. Under these conditions the greater portion of the gold—in fact, all except possibly the thinnest flakes—brought down by the streams from their swifter upper courses would be deposited where the change in gradient occurs. But the streams were carrying gold before the lava interrupted their flow, and the portions of their beds beneath the lava should contain the yellow metal. These old channels should be searched for. They may not be directly beneath the present streams, but may open into the canyons cut in the lava from the side, and possibly be a mile or two below where a stream makes its plunge into the canyoned portion of its course. The sides of the canyons are encumbered with talus and landslides, but excavations made where this material is thin should reveal the buried gravel, which might repay washing, and tunnels opened in it and beneath the lava covering would afford means of getting rid of the débris, so that the deposits on the surface could be worked. The possibilities of finding gold-bearing gravel beneath the Columbia River lava or interbedded with it are such that the contact of the lava with the underlying formations exposed along Snake, Salmon, and Clearwater rivers should be carefully searched.

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APPENDIX A.

ELEVATIONS IN NEZ PERCE REGION.

The following elevations are from surveys made by the Northern Pacific Railway Company, and have been furnished by Mr. E. H. McHenry, chief engineer. In each case they were taken either at the top of the tie opposite the center of the depot, or, where depots have not been constructed, at the center of sidings, and are from profile elevations reduced to sea level:

Elevations by Northern Pacific Railway Company.

	Feet.
Agatha (side track)	908.0
Ahsahka (side track)	1,002.0
Basalt (side track)	855.6
Caldwells spur	1,265.8
Cul de Sac spur	1,616.8
Juliaetta (depot)	1,084.0
Kamiah (depot)	1,197.8
Kooskia (side track)	1,263.0
Lenore (depot)	923.0
Lewiston (depot)	739.8
North Lapwai (depot)	809.0
Orofino (depot)	1,028.0
Peck (depot)	963.0
Potlatch (depot)	829.0
Stiles (side track)	1,320.0
Sweetwater (depot)	1,102.0
Weippe (side track)	1,088.8

The following elevations are from surveys made by the Oregon Railway and Navigation Company, and are above sea level:

Elevations by Oregon Railway and Navigation Company.

	Feet.
Top of State line monument on north bank of Clearwater River, at its mouth, near Lewiston	757.93
High-water mark at junction of Snake and Grande Ronde rivers	842.3
High-water mark on Snake River at boundary between Oregon and Washington	886.0
High-water mark at junction of Snake and Salmon rivers	965.0
High-water mark at Douglas, 57 miles above Lewiston ..	1,012.0

NOTE.—The elevations given in the body of this report are from aneroid measurements, which frequently could not be checked by comparison with definite bench marks, and must be taken simply as approximations to the actual heights of the localities mentioned.

APPENDIX B.

NOTES CONCERNING PORTLAND CEMENT.

Portland cement is an artificially prepared substance which has the property of hardening in the air when mixed with a suitable proportion of water, and of remaining hard when immersed in water. Its value lies in the fact that when used in masonry it produces a strong bond which does not weaken when submerged in water or exposed to a damp atmosphere. In its manufacture an intimate mechanical mixture of finely pulverized limestone, or marl, and clay is "burned" at a high temperature, and the resulting "clinker" is ground to a fine powder. The finished cement does not necessarily have a fixed and definite composition, but considerable variation may occur and an excellent product still be obtained. The degree of variation in composition usually considered allowable is indicated in the first column of the subjoined table. As is shown by the permissible variation in its finished product, there is considerable latitude allowable in selecting the raw material; but the limestone and clay need to supplement each other, so that when mixed in the proper proportions the resulting "slurry," as such a mixture is termed before being burned, will not vary in chemical composition beyond the approximate limits indicated in the second column of the following table:

Analyses showing permissible variations in the composition of Portland cement and in the slurry from which it is made.¹

Constituent.	Permissible variation.	
	Portland cement.	Slurry.
	<i>Per cent.</i>	<i>Per cent.</i>
Silica (SiO_2)	20 to 24	12.68 to 15.22
Alumina (Al_2O_3)	6 to 10	3.80 to 6.34
Ferric oxide (Fe_2O_3)	3 to 5	1.90 to 3.17
Calcium oxide (CaO)	60 to 64	38.04 to 40.58
Magnesium oxide (MgO)	1 to 3.5	0.65 to 2.25
Sulphuric anhydride (SO_3)	0.5 to 0.7	0.35 to 1.25

In the following table analyses are presented of the limestone, marl, clay, and shale used in the manufacture of some of the standard

¹ The writer is indebted to Prof. E. D. Campbell, of the University of Michigan, for the data herewith presented.

brands of Portland cement, or that have furnished satisfactory results in the making of small samples of cement in the laboratory:

Analyses of raw materials used in making Portland cement.

Constituent.	Limestone.		Marl.		Clay.		Shale.	
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Silica (SiO_2).....	3.53	2.14	0.52	0.20	59.15	61.68	65.25	49.93
Alumina (Al_2O_3).....	1.14	1.46	0.51	0.50	19.85	19.60	21.06	25.83
Ferric oxide (Fe_2O_3).....			0.53	0.60	8.30	3.12	3.40	6.05
Calcium oxide (CaO).....	54.45	52.84	51.66	50.12	3.03	2.40	0.84	3.12
Magnesium oxide (MgO).....	0.44	1.04	1.37	0.83	1.36	1.77	1.78	1.65
Sulphuric anhydride (SO_3).....			0.89	0.56		0.43		0.38
Loss on ignition.....	38.74	42.52	44.52	47.19	8.02	7.18	6.10	10.19
	98.30	100.00	100.00	100.00	99.71	96.18	98.43	96.65
Calcium carbonate (CaCO_3), computed.....	97.23	94.35	92.25	89.50	-----	-----	-----	-----
Magnesium carbonate (MgCO_3), computed.....	0.92	2.18	2.87	1.74	-----	-----	-----	-----

The foregoing analyses indicate the range in chemical composition which limestone (or marl) and clay (or shale) should have to be worth further investigation in reference to their use in the manufacture of Portland cement. A study of these data will show that the material to be used must be as free as possible from sulphur, the greatest amount of sulphuric anhydride (SO_3) permissible in the slurry being about 1 per cent, but, preferably, it should be below 0.5 per cent, and the magnesia also should be low, the greatest amount permissible under present American practice being about 3.5 per cent, although its influence on the properties of the finished cement is still under investigation. (Dyckerhoff, an eminent German authority on Portland cement, gives 4 per cent as the maximum for magnesia.) Other substances that frequently are present in the materials mentioned have in general but little deleterious influence, and may be considered adulterants. A general rule is that the sum of the ferric oxide and alumina in the slurry shall be about one-third of the amount of silica present.

In addition to the chemical composition of the raw materials it is desirable that they shall have certain physical properties. Chief among these there should be an absence of sand, for the reason that if the silica is in the form of quartz grains or kernels it will not unite with the lime in the desired manner when the slurry is burned; and the silica should be *combined silica*, as, for example, the aluminum silicate of clay. Both the limestone and the clay should be of such consistency that they may readily be reduced to a fine powder. The ideal lime ingredient is a soft, incoherent, fine marl, but if a limestone is used it is desirable that it be soft, so that the expense of grinding it to a fine powder may be reduced to a minimum. Still certain hard limestones are used, and the only objection to them, in case they have the requisite chemical composition, is the expense of grinding. The most desirable clay is one free from sand, which, when agitated in

water, will readily separate into fine particles. The best clays for this purpose are those having a greasy, unctious feel, and which are smooth to the touch. Hardened clay or shale is also used, but it has to be ground before being mixed with the lime to form slurry. It is highly desirable that the deposits both of lime and clay be of uniform chemical and mechanical composition throughout, in order to avoid trouble in combining them in the correct proportions.

In addition to the raw materials which enter directly into the composition of Portland cement, fuel is necessary for burning them. For this purpose, in the rotary kilns now generally used in this country, gas, petroleum, or pulverized coal is used. If coal is employed, it should be high in volatile matter, free or nearly free from sulphur, and low in ash, for the reason that it comes in direct contact with the cement-producing materials and influences the composition of the resulting product. The coal used by the Omega Portland Cement Company, of Michigan, has the following composition:

Analysis of coal used in manufacture of Portland cement.

	Per cent.
Moisture	1.00
Volatile matter	39.37
Fixed carbon	55.82
Ash	3.81
Total	100.00
Sulphur	0.92

The coal is pulverized so that it will pass through a sieve having 100 meshes to the line or inch, and is blown, by means of hot air, into the rotary kiln, where it burns, producing a long jet of flame.

In reference to the establishment of a Portland-cement industry in the Nez Perce region, it will be seen from the analyses of limestones presented that some of them at least have the desired chemical composition. The limestones on Mission Creek and that occurring in Snake River Canyon, for example, are of exceptional purity and well suited to this use. But the rock is hard, and could not compete commercially with a softer rock of equally favorable composition, provided the cost of transportation, etc., were the same.

The analyses of the ordinary soil and subsoil of the wheat lands show that they should be experimented with to determine their value as the "clay" ingredient of Portland cement. The doubtful feature is the comparatively high percentage of alkalies present, that is, potash and soda. This would tend to make the slurry easy to burn and to produce a quick-setting cement; but its influence can only be determined by actual trials. Small samples of cement could be made in the laboratory, and the behavior of the materials chosen thus be definitely ascertained. The writer suggests that a typical sample of the subsoil of the wheat lands, mixed in the requisite proportion

with the limestone that occurs on Mission Creek or in Snake River Canyon and properly burned, might yield a good Portland cement. The experiment is well worth trying. The soil of the wheat lands has in places been removed by streams and redeposited. This washed soil may be expected to be less rich in alkalies than the original material, and it might serve the purpose suggested, in case the soil occurring in place is found to be too high in potash and soda. The beds of clay interstratified with the Columbia River lava should also be tested.

Regarding fuel, the lignite occurring on Grande Ronde River and elsewhere might, perhaps, if finely powdered, answer the purpose. If not, the next most convenient source of supply would be the coal mines at Roslyn and Clealum, Washington. A commercial analysis of the Grande Ronde lignite has been given on a former page. Commercial analyses of the Roslyn and Clealum lignites, made by W. S. Thomas, of the Castner Coal and Coke Company, of Belt, Montana, are as follows:

Analyses of lignite from Roslyn and Clealum, Washington.

Constituent.	Clealum.	Roslyn.
	<i>Per cent.</i>	<i>Per cent.</i>
Moisture	5.55	2.05
Volatile matter	36.75	36.95
Fixed carbon	50.20	46.90
Ash	7.50	14.10
Sulphur	0.59	0.39

How the samples analyzed were taken is not known to the writer, and whether these analyses fairly represent the composition of the lignite at the respective localities can not be stated. It is doubtful, however, whether the average Roslyn lignite is as high in ash as is here stated.

In reference to the location of a Portland-cement plant, the chief consideration is transportation. As from three to five times as much limestone as clay is required, it usually follows that it is most economical to locate the plant near the source of the limestone; but the carrying of fuel must also be taken into account, as well as the direction of the market for the finished product.

On the whole, the conditions favorable to the establishment of a Portland-cement industry in the Nez Perce region are such that the matter deserves careful study.

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